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LIGHTNING AND LIGHTNING CONDUCTORS.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Weather Bureau,
Office of the Chief,
Washington, D. C., June 12, 1909.

Sir: I have the honor to transmit herewith a paper entitled "Lightning and Lightning Conductors," by Alfred J. Henry, professor of meteorology. This paper contains information respecting the phenomena of lightning in general and suggests means of protecting farm buildings from destructive lightning strokes. It is recommended that it be published as a Farmers' Bulletin.

Respectfully,

W. L. Moore,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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INTRODUCTION.

If the phenomenon of lightning were better understood, perhaps the enormous toll it exacts in life and property would be less. Carefully compiled statistics show that in the United States between 700 and 800 persons are killed annually and twice that number injured by lightning. This great loss of life falls largely upon the people who live away from the great centers of population. So, too, the greater part of the annual loss of property is chargeable to farm buildings and their contents and live stock in the field. Light and power electrical transmission lines also suffer from the vagaries of lightning, but the great multiplication of these lines in recent times has stimulated the development of means of protection, so that nowadays the electric power plants and lines are better protected from lightning than are farm buildings.

In what follows an attempt will be made to outline in nontechnical language a few of the most important laws of electrical phenomena. It is obvious that even a rudimentary knowledge of matters concerning the behavior of electrically charged bodies under various conditions will be of high value to persons who spend the greater portion of the day in the open.

Lightning, or more particularly a lightning flash, is a discharge of electricity between two electrified bodies, as between one cloud and another or between a cloud and the earth. Most of us are familiar with electricity and the varied economic purposes it serves. In all of these, however, it is under perfect control; it is chained, so to speak, by the wires which distribute it from the cell in which it is produced by chemical action, or from the generator which transforms the energy of the steam engine into electromotive force.

In order that the difference between the electricity that flows from a mechanical generator or other artificial source and that which abides in the atmosphere and on the earth's surface may be understood, it is necessary that first principles be considered very briefly.

ORIGIN OF ELECTRICITY.

It has been stated that electricity may be produced by chemical action or by mechanical means, but there are still other means by which a body may be given an electrical charge. Thus, if one rubs his feet over a woolen carpet several times and then touches his finger to the gas fixtures a slight spark will pass to the latter with an audible snap. In this experiment the body through friction with the woolen carpet receives a very light electric charge. The latter is discharged, or dissipated, as soon as the finger touches the gas fixture. This experiment is intended to show the ease with which a body can receive an electric charge.

CONDUCTORS AND NONCONDUCTORS.

Bodies do not all behave alike when an electric charge has been given them; thus some of them immediately conduct it away—in other words, the charge does not permanently reside on the body. To these bodies the name of conductor has been given, hence the term "lightning conductor" means a body that will conduct or lead away a lightning discharge. Other bodies have the quality of retaining an electrical charge for some time or of permitting it to escape very slowly. These are called nonconductors or insulators. A conductor, if supported by a nonconducting body, may also retain an electric charge, but the retention of the charge is due to the fact that the nonconducting support of the body prevents the escape of the charge. The metals are good examples of conducting bodies. Glass and gutta-percha are good examples of nonconductors or insulators. Telegraph lines, it will be remembered, are insulated from the poles by glass insulators. At one time it was thought necessary to insulate lightning rods from buildings by glass or porcelain insulators, but that view is not now generally held.

An electrical charge suddenly falling upon a conductor, say an iron rod, will be safely disposed of, provided the conductor is in connection with the earth. On the other hand, the same charge falling upon a piece of wood, the latter being a bad conductor, will split it into many fragments and possibly develop enough heat, by reason of the resistance offered by the wood, to set the latter on fire. For reasons above given, lightning conductors are made with a view of carrying the electrical charge safely to the earth through the medium of a good metallic conductor.

POSITIVE AND NEGATIVE ELECTRIFICATION.

In nature there are two kinds of electrification, viz, positive and negative; thus a body may be either positively or negatively electrified. The law of electrical attraction and repulsion is generally

stated as follows: Bodies electrified in the same manner repel one another; while bodies, one electrified positively the other negatively, attract one another. In the behavior of oppositely electrified bodies when brought near each other lies the key to many interesting facts in electrical science.

A positively charged body, if placed between two others, one having a positive the other a negative charge, will tend to move toward the latter, due, we are told, to the "electrical field" set up by the oppositely charged bodies. By an "electrical field" is meant the region in which work is done to move an electrical charge from one point to another. This work is susceptible of exact measurement; it varies inversely as the square of the distance separating the bodies, and depends also on the material of the nonconductor separating the bodies. The latter is generally called the "medium" or "dielectric;" thus the air separating one cloud from another, or a cloud from the earth, is known and referred to as the "medium" or "dielectric." For the purpose of this paper air will be considered as a nonconductor.

The force exerted in transferring an electric charge from one point to another, as before stated, depends upon the character of the medium through which it is transmitted. If the medium is a conductor, it will pass from one to the other harmlessly, but if the medium should be a nonconductor, such as the atmosphere, work will have to be done. The work done in the last-named case is manifest in lightning strokes by the rending and splitting of the objects struck, as before stated, and in this we find a reason for the rule in the erection of lightning conductors, viz, that the conductor should be continuous—there should be no air gaps in it, because a vast increase in the expenditure of energy on the part of the lightning stroke is necessary to cross the gap of nonconducting air. In this principle is also found an explanation of the fact generally observed in the case of a person struck by lightning, viz, that the shoes are almost always torn from the body and badly wrecked. The air gap between the body and the ground, although very small, is sufficient to produce the observed effect.

A point has now been reached when it is necessary to introduce another technical term, viz, "electrical potential," or simply "potential." The idea conveyed by "potential" is of the same nature as that of difference in level in case of water; thus water always flows from the higher to the lower level, and the force with which it flows depends, among other things, upon the amount of the difference in level. So in electrical terminology a current of electricity flows from a body with a high potential to a body with a lower potential; or, in other words, the distribution of the electric charge on both bodies

is very materially changed when they are brought into conducting communication.

In the definition of a lightning flash on a previous page one of the great differences between a lightning flash and the ordinary electric current was not pointed out, viz, the first differs from the second in that it is at a much higher potential; that is, the force or pressure that impels it is tremendously greater than that which, for example, causes an electric current to flow along a trolley line. The latter flows under small pressure through a conductor, while the former breaks down the air, a nonconducting body, throughout a path sometimes more than a mile in length.

To recapitulate: Thus far it has been shown that a body may receive an electric charge in several ways; that there are two kinds of electrification; that different bodies behave differently with respect to holding electrical charges; that there is an attractive force between bodies oppositely electrified, and some of the laws that govern the transmission of an electric charge from one body to another have been pointed out. There is another method by which an uncharged body may be electrified, viz, by bringing it into the field of a charged body. This method is known as the phenomenon of induction. It is of importance in the erection of lightning conductors, as will now be shown.

Let there be any two parallel wires close together. Through one of them, A, pass an electric current. The flow of this current will induce a current in the other wire, B, in a direction opposite to that in A. Telegraph and telephone lines carried on the same poles are operated with great difficulty because of the induced current set up in the telephone wires by the current flowing through the telegraph wires, and certain devices have to be applied to the former in order to overcome the induction effects.

The application of this principle to lightning conductors lies in the fact that a stroke of lightning falling on the lightning rod is liable to set up side flashes in the metal work of the building that may be near to the lightning conductor. The remedy will be found in the concluding part of this paper.

Franklin was the first to point out that an electrical field exists in the atmosphere during thunderstorms. Later investigators have shown that an electrical field is present in the lower atmosphere even in fair weather, such that a positively charged body would be attracted toward the surface of the earth. We are also told that the surface of the earth is always negatively charged, and further that the charges on these two bodies, viz, the lower atmosphere and the earth's surface, though opposite in character, do not permanently neutralize each other, as might be expected. On the contrary there is a tendency in the electrical condition of air and earth

to depart from what might be called normal conditions of fair weather and pass into conditions of great strain in the air which separates one cloud from another or from the earth. This condition of great stress is found in thunderstorms; it is relieved by disruptive discharges from cloud to cloud and from cloud to earth. Once equilibrium is established there is a period of quiet, and then another period of increasing electrification followed by thunderstorms.

ELECTRICITY IN THUNDERSTORMS.

This problem has been freely discussed for several centuries; it has been attacked from many view points and much laboratory work has been done in order to produce a discharge that, in a small way, may be comparable to those observed in nature. Still it can not be said that the precise mechanism of a thunderstorm is known. The most recent theory is one put forth by Dr. George C. Simpson.[a] Doctor Simpson has proven by laboratory experiments that when a large drop of water is broken up into smaller drops in the air the water becomes positively and the air negatively charged. In other words, when each drop of water is broken up a certain number of units of free negative ions and a less number of free positive ions are released. (An ion is understood to be any extremely small material particle which carries a charge of electricity.)

He has further shown that every time a drop breaks a separation of electricity takes place, the water receiving a positive charge and the air a corresponding negative charge. The charge which passes to the air is rapidly absorbed by the cloud particles, and in time the cloud itself may become highly charged with negative electricity. The relation of these facts to the development of thunderstorms will now be pointed out. The latter, it may be remembered, occur for the most part on warm, sultry days; the usual preliminary is the formation of a cloud with a flat base whose summits—for it generally has several—are rounded and tower far into the sky. These rounded summits are the tops of ascending currents of warm air whose moisture, condensed by the cold of elevation, forms the white domelike structure of the cloud. The existence of an ascending current is beyond question; just what velocity the ascending air has is yet somewhat conjectural. A velocity of 18 miles an hour, however, is required by the theory under discussion. Lenard has shown that drops having a diameter greater than two-tenths of an inch are unstable when falling through the air and rapidly break into smaller drops; also that all drops having a diameter less than two-tenths of an inch have a final velocity when falling through the air of less than 18 miles an hour. Thus it will be seen that in the ascending air

[a] Proceedings of the Royal Society, series A, vol. 82, p. 169.

currents of a thunderstorm no water can fall provided the ascensional velocity is 18 miles an hour or greater; for all drops less than two-tenths of an inch in diameter are carried upward, and all drops having a larger diameter quickly break into smaller drops. The above facts, together with his observations and experiments, lead Doctor Simpson to formulate the following theory for the origin of electricity of thunderstorms:

It is exceedingly probable that in all thunderstorms ascending currents greater than 18 miles an hour occur. Such currents are the source of large amounts of water which can not fall through the ascending air. Hence at the top of the current, where the vertical velocity is reduced on account of the lateral motion of the air, there will be an accumulation of water. This water will be in the form of drops which are continually going through the process of growing from small drops into drops large enough to be broken. Every time a drop breaks a separation of electricity takes place, the water receives a positive charge, and the air a corresponding amount of negative ions. The air carries away the negative ions, but leaves the positively charged water behind. A given mass of water may be broken up many times before it falls, and in consequence may obtain a high positive charge. When this water finally reaches the ground it is recognized as positively charged rain. The ions which travel along with the air are rapidly absorbed by the cloud particles, and in time the cloud itself may become highly charged with negative electricity. Now, within a highly electrified cloud there must be a rapid combination of the water drops, and from it considerable rain will fall; this rain will be negatively charged and under suitable conditions both the charges on the rain and the rate of rainfall will be large.

A rough quantitative analysis shows that the order of magnitude of the electrical separation which accompanies the breaking of a drop is sufficient to account for the electrical effects observed in the most violent thunderstorms. All the results of the observations of the electricity of rain described above are capable of explanation by the theory, which also agrees well with the actual meteorological phenomena observed during thunderstorms.

Whatever may be the origin of the electricity of the air, its effects upon the various terrestrial objects upon which it falls are well known. From its effects we are able to infer that the intensity of the charge in the lightning flash varies between very wide limits. Not every discharge is heavy enough to take life or badly splinter a tree, so that we can at once distinguish between light flashes generally harmless and heavy flashes which splinter trees or kill live stock and human beings. A third class may also be recognized, viz, the violent disruptive discharge, which, as pointed out by Sir Oliver Lodge, is the result of a discharge initiated elsewhere, such, for example, as when one cloud discharges to another cloud between it and the earth. When this happens the free charge on the earth side of the lower cloud will be suddenly relieved and fall upon the earth through previously unstrained air as a discharge of the most violent and explosive type.

When a thunderstorm develops and moves over the land the air between the under surface of the cloud and the earth's surface is

able at first to resist the passage of a discharge between cloud and earth, but as the electrification increases the strain in the air becomes too great and a discharge follows. The zone of danger in a thunderstorm is, therefore, generally equal to the area of the cloud itself, sometimes extending a little to the front of the cloud. The heaviest discharges pretty nearly always occur simultaneously with the passage of the storm front. The reason for this can be very easily shown in the laboratory; thus it is well known that if the two poles of a charged electric machine are brought near to each other a spark will pass from one to the other. Now, in order to get the first spark the poles of the electric machine must be brought nearer together than is necessary after several sparks have passed. The passage of several sparks through the air separating the poles evidently electrifies it, and thus it becomes a better conductor.

The area within the storm cloud is what may be called a "danger zone." Within this zone almost any upright object, especially a tree, is a better conductor than the air itself, and is consequently liable to lightning stroke. For this reason to take refuge under a tree is a dangerous proceeding. Other places to avoid are near chimneys or fireplaces and in close proximity to wire fences. The latter, as has been repeatedly stated in agricultural journals and the publications of the Weather Bureau, should be grounded at every fifth post. To successfully ground a wire fence attach to the fence post with staples a piece of galvanized wire, so that some part of this wire will come into actual mechanical contact with the fence wire and extend thence about 2 feet into the ground. A bolt of lightning which may fall upon a wire thus grounded will be quickly carried to the earth and rendered harmless.

The ordinary farm building is not difficult to protect from lightning flashes in the great majority of cases. While absolute protection can not be secured unless the building be incased in a network of wires, it is believed that a building with a properly installed system of lightning conductors will fare better than one without such a system in case a discharge of the most violent type should fall upon it.

Whether or not to install lightning conductors on one's property is a question, after all, of individual judgment. If the property is insured against loss by lightning there would be little incentive toward incurring additional expense for lightning conductors. In case of an isolated farm building standing apart from trees it would seem that the conservative course would be to erect an inexpensive system of lightning conductors, such as will be described in the concluding part of this paper.

LIGHTNING RODS FOR FARM BUILDINGS.

It is proposed to give in what follows instructions which will enable anyone to erect a comparatively inexpensive yet effective lightning conductor, with materials that can be purchased from the larger electric supply houses.

The case of a building on which there is neither cupola nor chimney will be discussed first. Such a building and the method of rodding it is shown in figure 1.

MATERIAL.

The material necessary for the construction shown in figure 1 consists of (a) sufficient length of No. 3 or No. 4 double galvanized-iron telegraph wire, (b) about a pound of galvanized-iron staples, (c) three or four connecting tees, (d) 1 pound of aluminum paint. While iron is not so good a conductor as copper it is less likely to cause dangerous side flashes, and it also dissipates the energy of the lightning flash more effectively than does the copper.

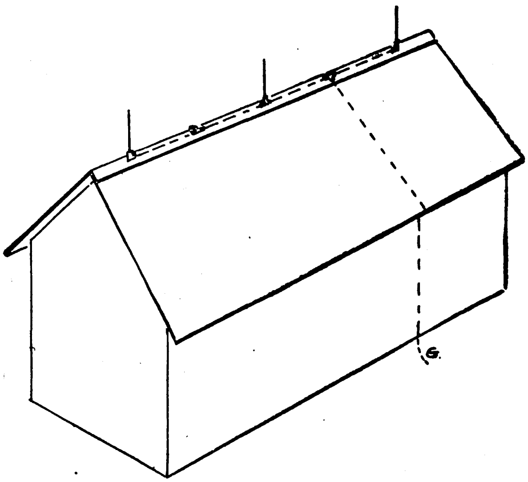

FIG. 1.—Method of placing lightning rods on a building having no cupola or chimney. Length of building, about 25 feet.

The high price of copper cable adds greatly to the price of manufactured lightning rods made out of that metal. An experiment performed by Sir Oliver Lodge before a committee studying the effect of lightning on various conductors bears directly on the utility of copper and iron as lightning conductors. It is here given:

A thin sheet of metal mounted on nonconducting standards represented the cloud, which was charged at will from a Leyden jar. The "cloud" was so arranged that the model lightning conductors could have their points brought nearer to or farther from its under surface by shifting their positions on the table. Conductors of copper, iron, and wet strings were experimented with. The disruptive discharge to the copper proved to be the loudest and most intense by far of the three. The iron took the flash with less noise, the wet string with hardly any; yet when the discharge passed through it the other and apparently better conductors were not affected. The experiments tended to demonstrate that iron is in many situations a very useful material for lightning rods, as the effective energy of a flash of lightning is rapidly dissipated in iron.

Iron oxidizes rapidly when exposed to the air; it is necessary, therefore, that it be galvanized. In the trade there is both single and double galvanized. Double galvanized or Extra Best Best should be used. There are several gauges in use by wire manufacturers both in this country and abroad. The differences between one gauge and another are not great, yet it should be remembered, for example, that the "B. & S." gauge (Brown & Sharpe) is smaller than either the Roebling (John A. Roebling & Sons) or the Birmingham wire gauge of England. No. 2 wire, B. & S. gauge, measures 0.257 inch in diameter. To get approximately the same diameter in the Roebling or the Birmingham gauge No. 3 wire should be procured. The diameter of the latter is roughly a little over a quarter of an inch.

The size of wire here recommended for lightning conductors (No. 3 or No. 4) is less than that prescribed for main conductors by the English Lightning Research Committee of 1905. The only objection that can be urged against the smaller wire is that of insufficient capacity. Some years ago the opinion was prevalent that the sectional area of an iron conductor should be six times as great as that of a copper conductor. It was also believed that the diameter of a copper conductor should be not less than three-eighths of an inch. Accordingly for a main conductor of iron it would be necessary to erect a rod over 2 inches in diameter. Such a size would nowadays not be considered as either necessary or practicable. The ordinary telegraph wire has a diameter of about fifteen one-hundredths of an inch; it is often struck by lightning, yet it is seldom fused. It is probable that, although a light iron wire may be melted, it will have served its purpose before being destroyed. No. 3 wire is about twice the size of telegraph wire (No. 9). So large a wire is rarely, if ever, used in telegraph circuits, but it comes into use on high-power electric transmission lines. The writer does not know of a case wherein that size has been fused by a lightning discharge, and therefore feels no hesitancy in recommending its use as a lightning conductor for isolated farm buildings of moderately small heights.

There are other forms of soft iron conductors that would serve as lightning rods, particularly the lighter cables, say three-eighths of an inch in diameter. This form of conductor has the advantage over a solid conductor of the same size in that it is more easily handled. It can be bent over the eaves of a building or around an obstacle more readily than the solid wire, and the ends admit of being fuzzed out like a broom. The additional points thus gained serve a useful purpose on the upper ends of the terminals. Soft iron wire cable, double galvanized, is not so easy to obtain as the solid wire, and for that reason preference is given the solid wire.

The T connections are shown in figure 2. They should be galvanized in order to protect them from the corrosive influences of the atmosphere.

When the length of a lightning conductor is increased, as in a building of greater dimensions than shown in figure 1, the increased resistance of the wire is equivalent to a diminution of the sectional area; accordingly a larger size of wire should be used, that is to say, if a No. 4 wire is used on a small building, No. 3 should be used on a larger one.

DIRECTIONS FOR PUTTING UP WIRES.

The conducting system is composed of a horizontal wire following the ridge of the roof and two vertical wires connecting with the ground on both sides of the building.

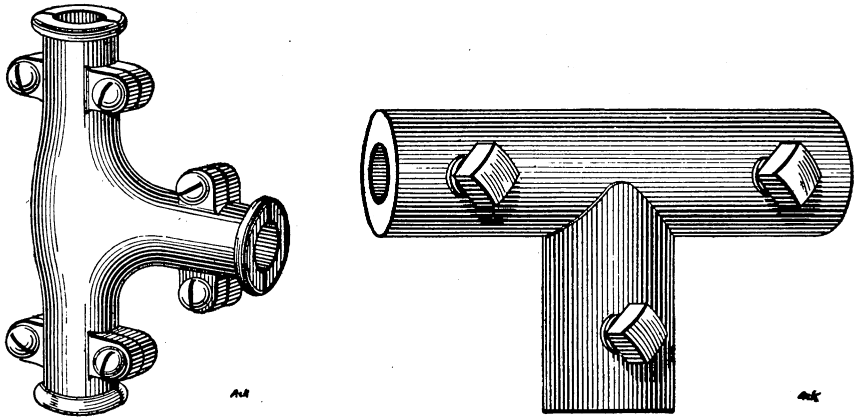

FIG. 2.—Two types of T connections.

The wires should be fastened to the building by galvanized iron staples about an inch long; they are not to be insulated from it as was once the practice. Another way to fasten the wire to the building is by means of small wooden blocks and screw eyes. Blocks 1½ inches thick, 2½ inches wide, and 4 inches long into which a stout screw eye is fastened may be nailed to the sides and roof at intervals of 10 feet or less. The wire can be easily passed through these eyes from the ground to the top of the building.

The vertical wires should be connected to the horizontal wire by galvanized iron tees (fig. 2). The necessary tees should be slipped onto the horizontal wire and placed at points of junction with the downward directed wires, and also at such points as it is wished to erect short terminal rods along the ridge of the roof.

TERMINALS.

Three terminals are shown in figure 1. These rods need not be more than 20 inches long. The end terminals are best formed by making a right angle bend in the wire which runs along the ridge of the roof at a distance of 20 inches from the respective ends. The middle terminal is merely a wire 20 inches in length held in place by a T connector. The terminals are short and offer little resistance to the wind; they are kept in a vertical position by the connections between the ridge wire and the wires leading to the ground.

The end of the upper terminal should not be left blunt, but should be filed down until it is cone shaped. Since the filing removes the galvanizing over the surface of the cone, the latter should be heavily coated with paint to preserve it from rust.

In general a terminal rod should be erected every 18 or 20 feet along the ridge of the roof.

The number of terminal wires depends on the number of cupolas, chimneys, or other salient points on the roof liable to be struck. A short terminal wire connected to the main conducting wire by a tee should be erected at each cupola or other salient point. The method of running the horizontal conductor around a chimney or cupola is shown in figure 3.

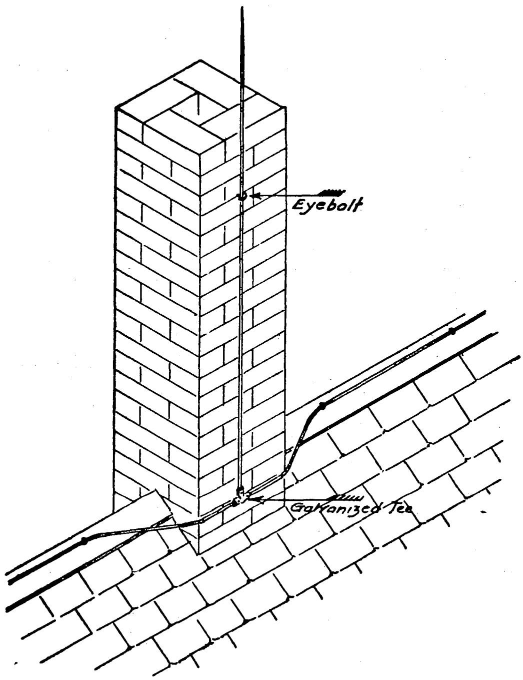

FIG. 3.—Showing method of running horizontal conductor around a chimney or cupola.

EARTH CONNECTIONS.

The earth connections require great care in their construction. The essential thing is to reach permanently moist earth in the shortest distance from the main conductors. The building shown in figure 1 has two ground connections, one on each side of the building. Two kinds of ground connections are suggested. The ground ends of the vertical conductors, or wires, should be coiled in a spiral having a diameter of about a foot. These spirals should be buried

in moist earth at whatever depth the latter is found. If there are no down rain spouts on the building the ground connection should be placed in the line of the drip from the roof, since the latter has a tendency to keep the earth moist. This construction has the advantage of an unbroken run of wire from the ground to the roof of the building. When the main conductors run from the roof of the building to the base only there is often trouble in making a perfect joint between them and the materials used for ground wires. It is a distinct advantage to have the entire system of one and the same kind of conducting material.

The second suggestion is to take a galvanized water pipe, say an inch and a quarter in diameter, and drive it into the ground at the foot of the main conductors. Secure a cap for the top of the pipe and bore a hole through it so that the conducting wire can be passed through; then insert the wire into the iron pipe, fill the interstices with powdered charcoal, and place the cap on the pipe. The hole in the cap should be large enough to permit the conducting wire to pass easily through and at the same time allow water to pass down the wire into the interior of the pipe.

The number of ground connections in the simple case considered in figure 1 is but two, one on each side of the building. When the size of the building is increased, more vertical wires will be needed and consequently more ground connections. The number of such connections, therefore, will depend on the number of vertical conductors. In general, it is advisable to run a vertical conductor up the side of a building for each 25 or 30 feet of its length; thus, for example, a barn 56 feet long should be equipped with at least two vertical conductors on opposite sides of the building.

BUILDINGS WITH METALLIC ROOFS.

A metallic roof properly connected to the earth affords a reasonably good protection to the building from lightning. In suburban districts where frame buildings with tin roofs prevail there is little destruction by lightning; most of the buildings have down rain spouts, which serve to conduct the discharge to the earth. In the case of an isolated building with a tin roof care should be taken to see that the down rain spouts are connected with the ground. It will not do to stop them within a few inches of the ground; there should be an unbroken metallic path from the ridge of the roof into the ground.

In providing a ground wire to connect the lower end of a rain spout with moist earth, a wire such as hereinbefore described, a wire cable, or a piece of galvanized pipe may be used. The vital points of the connection are two; first, to reach permanently moist earth

and, second, to secure a perfect metallic joint between the down spout and the earth conductor. If a wire is used it should be flattened out at the end in the form of a tape and then bolted and soldered to the rain spout. This form of a joint is not very durable, since the tin is apt to oxidize unless it is kept well painted.

In the case of a building with a metal roof, but no down spouts, it is desirable, in order to obtain protection from lightning, to run a wire conductor from each of the four corners of the roof to the earth. The precautions described in the preceding paragraph as to making good metallic joints should be observed.

The foregoing is applicable to the simplest form of construction. As the size of the building to be wired increases, the difficulties in wiring also increase somewhat. The longer the total run of the wire the greater becomes the electric resistance; to offset this the sectional area, or the diameter of the wire, should be increased, as before stated.

In determining the size of the wire to be used the following may be helpful: If the building is small, such as shown in figure 1, a short run of wire will answer, viz, up one of the longer sides of the building, along the ridge of the roof, and down the other side. In this case use No. 4 wire. The size of the wire diminishes as the numbers increase. Thus a No. 3 wire is larger than a No. 4, their respective diameters (B. & S. gauge) being as follows: No. 3, 0.244 inch; No. 4, 0.225 inch. If the building is large enough to require two vertical wires on each side of the building and a wire along the ridge of the roof, it would be advisable to use No. 3 wire.

All objects on a building higher than the ridge of the roof should be protected by short terminal wires, and the latter should be joined to the main conductor provided the distance is not over 10 or 15 feet. If the distance is greater it would be better to run a conductor direct to the ground, the usual precautions as to reaching permanently moist earth being observed.

The form of wiring when passing a chimney or a cupola is shown in figure 3. It will be noticed that the bend in the wire is gradual, not abrupt. The terminal wire for the chimney should be erected at the point shown in the drawing. Likewise in passing over the eaves of a building a goose-neck bend is preferred to a sharp one.

If the overhang of the roof is excessive, a hole should be bored through it to let the wire pass close to the wall of the building.

The following-named points not specifically mentioned in the text should be observed:

(1) If there are gas pipes in the building keep the lightning conductors away from them as far as possible. On the contrary, large masses of metal, such as water pipes, should be connected to the

conductors. The water pipes should be in good connection with the ground.

(2) Joints should be held together mechanically and should be frequently examined to see that they are not broken.

PAINTING.

The whole system should receive two coats of aluminum paint; it should be repainted every few years.

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